assessment form the planned isodose coverage was reviewed for clinical suitability.

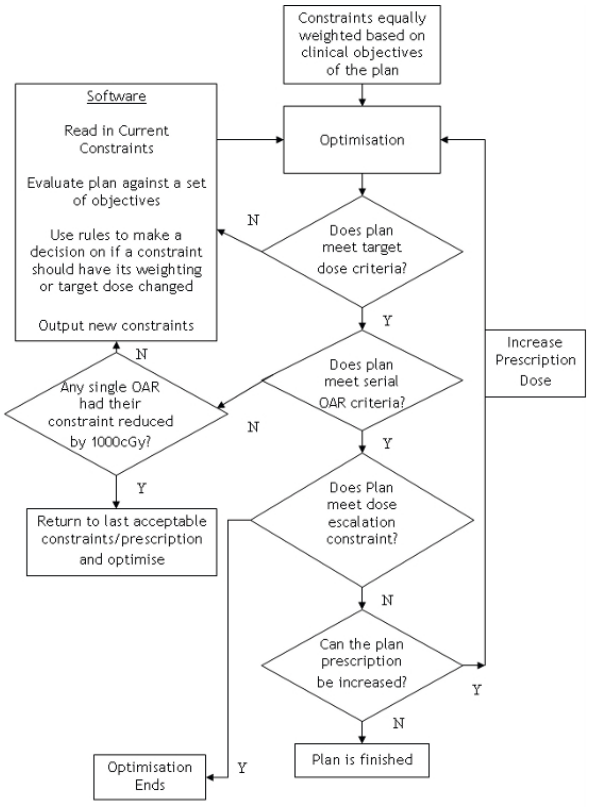

Figure 1: Flow Chart Demonstrating the Process of the Automated Planning System

Results: Dose escalation was possible for all patients above 55.8Gy. Upon evaluation all serial OAR are within tolerance. The 'one size fits all' approach of the same set of starting constraints for all patients creates varying degrees of success in terms of 90% isodose coverage. Increased dose prescriptions created more inhomogeneous distributions. For each possible prescription the system outputs the optimised constraints to allow for an informed choice in terms of the final prescription dose to be used. The automated method took on average 4-6 hours to complete the process.
Conclusions: The automated dose escalation planning system shows promise as a tool for reducing the time required to carry out isotoxic lung planning. The plans produced all met the objectives given to the system. The system creates plans that are an excellent starting point for a planner to create a clinically acceptable plan.

PO-0833
Voxel-based dose-painting with a commercial treatment planning system by using two different planning methods
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Purpose/Objective: The interest in radiotherapy treatment planning which incorporates metabolic information obtained by non-invasive tumour imaging, and the consequent capability of targeting the identified biological regions with the appropriate radiation doses, has increased the interested in dose-painting techniques. These approaches, by which the dose distribution is modified to take into account the local characteristics of the tumour, generally require specific inverse-planning engines where the 'biological' properties associated with each individual target voxel are considered into the optimization phases. Since such devices are not yet present on the market, two methods based on a commercial treatment planning system (TPS) together with an external bio-optimization tool (TaBio) were applied and compared.
Materials and Methods: The best theoretical dose for each voxel of the target, as a function of the corresponding signal intensity maps of the biological tumor imaging analyzed, has been realized. To achieve this goal, an homemade inverse-planning tool was realized where objective functions (TCP - tumor control probability and EUD - equivalent uniform dose) can be selected to guide the target integral dose (kept constant) redistribution. The dose patterns obtained were then reprocessed in two different ways. In the first case, geometric structures have been realized by matching the shapes of some isodose levels opportunely selected. In the second case instead, the calculated doses have been inverted to create specific dose moulds. Both these objects have been so exported to a TPS (Eclipse, Varian) and used as dose maps gold standard to be replicated. The critical-organ dose constraints were added in the optimization process, while for the second method, a uniform target dose distribution was required in addition. Five patients have been simulated to verify these two approaches, where the Standard Uptake Values of Fluoro-Choline (PET/CT) imaging has been used as a surrogate marker for their prostate tumor clonogen-densities.
Results: Although neither planning approach was able to replicate the theoretical biologically estimated dose maps, the dose contour's based method has proved to be the most accurate in reaching 'acceptable' dose patterns. Since the TCP-based optimizations generally result in dose maps which are more heterogeneous (mean coefficient of dose variation CV = 6.8%) and with larger voxel-dose ranges than the EUD-based optimizations (CV = 4.6%), such solutions deviating most from the theoretical. The use of EUD-based optimization would seem to be the easiest way to follow.
Conclusions: Being able to include, on a voxel-based scale, the Fluoro-Choline PET data into the dose optimization process, the method of dose-contours seems more able to yield acceptable and deliverable dose-painting treatment plans.

PO-0834
Investigation of IMRT dose optimization with gEUD-based objective using a linear programming approach.
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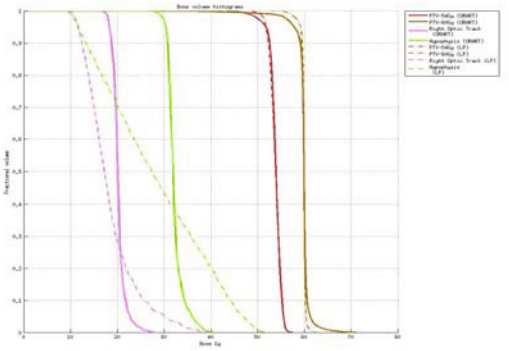
Purpose/Objective: The purpose of this study is twofold: first it aims at exploring the effectiveness of a linear programming approach for finding beamlet's weights in IMRT; secondly it aims at investigating the usefulness of the so obtained solution as a qualified starting point for a further non linear IMRT optimization.
Materials and Methods: In IMRT treatment planning the goal is to find an optimal compromise between organ at risk (OAR) sparing and target coverage: given a prescription, one needs to ?nd a beamlet intensity vector so that the calculated dose from it will satisfy the prescription as closely as possible. We solved a linear programming (LP) optimization problem to minimize the deviation in dose from a prescribed dose on target and the maximum dose allowed on OARs. The choice of a linear programming approach was due to the easiness of formulating and solving the problem.for large treatment plans. To set up simulated treatment, we used the research treatment planning system CERR (computational environment for radiotherapy research) based on the MATLAB environment. One brain and one prostate cancer patient were selected for 7 field IMRT treatment optimisation. For these case we investigated the effectiveness of the beamlet solution obtained by solving the LP problem and the usefulness of using that solution, as a starting point for gEUD based optimization. In fact, gEUD based optimization is non convex and may result in multiple local minima, therefore the choice of a starting point is crucial. The LP approach has been finally compared with the dosimetric optimization based on the weighted least squares objective function used in the routine Operation-Research-Application in Radiation-Therapy (ORART) of CERR.
Results: We found that LP solution exhibits an improved sparing of normal tissues and a better target coverage than the one obtained with ORART. The figure shows the comparison of DVHs of a brain plan with dosimetric optimization with ORART (solid lines) and with the LP approach (dashed lines). The PTV54 and PTV60 represents the two different planning target volumes treated with 54 GY and 60 Gy respectively. Besides supplying a good treatment plan, LP solution gives an improvement (both in terms of DVHs and gEUD values) in gEUD based optimization when used as a starting point. For example, we found for the brain plan, an improvement on the gEUD values: 14.14 versus 16.41 for right optic tracts and 25.6 versus

26.5.for hypophysis. For PTV54 and PTV60 we found 51.5 and 58.9 gEUD values with LP based initial point, compared to 51.7 and 57.9.
Conclusions: The results indicate that the approach of using linear programming is an effective way to easily obtain a good plan and to improve gEUD based optimization.



PO-0835
Ultra-fast arc therapy planning framework
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Purpose/Objective: We introduce an ultra-fast optimization framework for arc therapy and highlight the potential of non-coplanar arcs.
Materials and Methods: The implementation of the arc therapy planning is based on [Bzdusek et al. MedPhys 2009]. First, an IMRT fluence optimization (FO) using 24 equi-spaced coplanar beam orientations is performed and the resulting fluence profiles are sequenced. From every IMRT beam orientation, three shapes are selected according to the dose area product and distributed to 72 equi-spaced coplanar beam orientations used for arc therapy optimization. The initial shapes are refined using a gradient based direct aperture optimization (DAO) algorithm. Both FO and DAO are performed at 2.62 x 2.62 x 2.62 mm^3 voxel and 5 x 5 mm^2 bixel resolutions. During inverse planning, we use an ultra-fast dose, gradient, and objective function calculation engine which was originally developed for a beam angle selection algorithm to accelerate the optimization process.
As a first application we use our framework to compare three different plans:
1. Coplanar arc therapy plans
2. IMRT plans with 9 beams, non coplanar, beam angle optimized
3. 4 π plans, not sequenced
The 4 π plan is an IMRT plan with up to 1400 beam orientations using every practicable direction. An intra cranial, a pancreas, and a prostate case are examined for each type of plan.
The framework is tested on an AMD Opteron workstation (4 CPUs, 1.9 MHz, 128 GB RAM, US$ 5000).
Results: We observe runtimes of less than 25 s for an arc therapy optimization excluding the initial calculation of the dose influence data (see table 1).

Case	Size of data	Iterations (IMRT)	Iterations (DAO)	Time
Intra cranial	1.13 GB	21	30	6.9 s
Pancreas	3.92 GB	21	53	23.8 s
Prostate	3.49 GB	21	70	24.5 s

Table 1: Optimization parameters for arc therapy plans.

For the intra cranial case (DVHs in figure 1) the target conformality of the arc plan is comparable to the 4 π plan (van't Riet's conformality numbers of 0.86 and 0.9). The target conformality of the non coplanar plan applying 9 optimized beam orientations is significantly decreased (0.72).

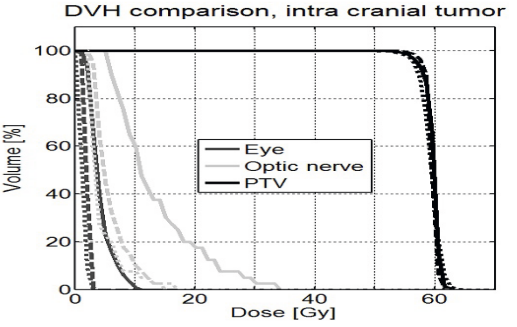

Figure 1: Arc plan, 72 beams, coplanar (line); IMRT plan, 9 beams, non coplanar, sequenced (dotted); IMRT plan, 1376 beams, 4 pi (dashed)

Using non coplanar beams, however, it was possible to spare the organs at risk (OARs) in a better way than with the coplanar arc plan. For the nine beam IMRT plan, the mean (max) dose of the left eye can be reduced from 4.1 Gy (10.7 Gy) to 1.2 Gy (2.8 Gy). Also the left optical nerve receives only 4.4 Gy (17.0 Gy) instead of 13.3 Gy (34.2 Gy).
For the less complex pancreas case we observe similar but weaker effects regarding the improvement of OAR sparing than for the intra cranial case. The different plans of the prostate case show only slight differences.
Conclusions: We demonstrated that it is possible to optimize arc therapy plans in less than 30 s. Our preliminary treatment plan comparison indicates that for complex geometries, non coplanar beams may enable superior OAR sparing than a conventional coplanar arc plan. Hence, we want to use the developed ultra-fast arc therapy optimization framework to study the benefit of non coplanar arc therapy in future investigations.

PO-0836
Stochastic frontier method for IMRT planning optimisation based on geometry
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Purpose/Objective: Ideally, Intensity modulated radiation therapy (IMRT) should allow the conception of treatment plans with equivalent curative outcomes and better normal tissue sparing than those obtained with traditional techniques. It is however always necessary to make some compromises between PTV coverage and OAR sparing. Such compromises are often dependent on the person preparing the plan. To accelerate, standardize and increase efficiency of future planning, we aim to determine some criterions based on patient specific geometry by using parameters such as the distances between targets and OAR and the amount of overlap between them. These parameters were adjusted by doing a retrospective study of head and neck IMRT plans.
Materials and Methods: Maximum and mean dose to some OARs were put in relationship with distance between OAR and PTVs, overlap volume and overlap gradient on the first centimeter of PTV. Here, only the lower bound is of interest to attempt to predict the lower dose reachable as a function of the geometry. Stochastic frontier production method, as used in economics, was adapted to model the frontier, i.e. the lowest achievable dose to OAR. This method assumes a mix of deterministic and stochastic distributions of OAR doses, near an optimal frontier. Maximum likelihood is used to extract the frontier function, dependent on the relevant geometric parameters.
Results: Eighty patient cases were analyzed with this approach and a good relation was obtained between the overlapping volume and the mean dose of the parotid. Some adjustments must be applied when overlap with higher dose level of PTV is present to get a more precise frontier. The method is now currently extended to other OARs like larynx and to other sites like pelvis.
Conclusions: Frontier analysis showed promising potential. More than one parameter can be included to get a more precise frontier that lead to a more optimal plan. Also this approach can reduce the planning time. In future work we will introduce these criteria to our dosimetrists and evaluate possible gains in efficiency.

PO-0837
PTV spells paranoid target volume
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